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ABSTRACT

This student manual, the third in a set of 14 modules, is designed to train emergency medical technicians (EMTs) in Ohio. The module contains one section covering the following topics: general anatomical terms, the body cavities and contents, the integumentary system, the skeletal system, the muscular system, the nervous system, the respiratory system, the circulatory system, the digestive system, the urinary system, the reproductive system, and the endocrine system. The section contains 13 objectives, an introduction, and information text. The text is illustrated with line drawings and photographs. (KC)

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EMERGENCY VICTIM CARE

ED239056

Module 3 —Anatomy and Physiology

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This text is intended for use as a learning aid and to excite your curiosity and eagerness to serve patients. This text is not exhaustive and the opinions and directory comments will change from time to time as new procedures and laws become effective.

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EMERGENCY VICTIM CARE

A TRAINING MANUAL FOR EMERGENCY MEDICAL TECHNICIANS

OHIO TRADE AND INDUSTRIAL EDUCATION SERVICE

DIVISION OF VOCATIONAL EDUCATION
STATE DEPARTMENT OF EDUCATION
COLUMBUS, OHIO

TO THE LEARNER

The 1983 Emergency Victim Care textbook revision has been grouped into 14 modules. The modules have been grouped by content matter as follows:

Module 1

Preface
Foreword
Acknowledgment
Student-Instructor Relationship

Personnel
Emergency Medical Service Vehicles
EMS Communication
Records and Reports

Module 2

Equipment
Safe Driving Practices
Legal Aspects
Controlling the Situation
Action Evaluation Conference

Module 3

Anatomy & Physiology

Module 4

Vital Signs
Patient Assessment

Module 5

Cardiopulmonary Resuscitation (CPR)

Module 6

Bleeding Control
Wounds and Bandaging
Shock

Module 7

Medical Emergencies

Module 8

Crisis Intervention
Drug-Related Problems

Module 9

Backboards/Moving and Handling the Victim
Fractures
Dislocations

Module 10

Injuries of the Eye, Ear, Nose, Abdomen, C.N.S. and Genitalia
Burns and Environmental Injuries

Module 11

Childbirth
Pediatric Emergency

Module 12

Water Accidents
Electrical Emergencies
Hazardous Materials and Radiation Accidents

Module 13

Extrication from Automobiles

Module 14

Appendix I: Communicating with Deaf and Hearing Impaired Patients
Appendix II: Medical Terminology
Appendix III: EMS Organizations
Appendix IV: Legislation
Glossary of Terms
Index

ANATOMY AND PHYSIOLOGY

OBJECTIVES

Upon completion of the following chapter, you will be able to:
—locate the basic anatomical structures of the human body.

Following instruction and/or practice, you will be able to:
—identify the five body cavities.
—list the four abdominal quadrants and contents.
—list the functions of the integumentary system.
—identify on a sketch or model of the skeletal system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the muscular system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the nervous system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the respiratory system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the circulatory system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the digestive system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the urinary system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the reproductive system the major anatomical structures and describe their physiology.
—identify on a sketch or model of the endocrine system the major anatomical structures and describe their physiology.

INTRODUCTION

To prepare the EMT to render emergency care efficiently and intelligently, it is necessary for the EMT to have an understanding of the structure (anatomy) and the workings (physiology) of the human body and its important organs and systems.

GENERAL ANATOMICAL TERMS

The EMT should understand certain anatomical terms in relation to position of the human body. In describing the body, anatomists always consider it to be in the erect position facing toward the observer, arms hanging at the sides, and the palms of the hands turned forward. See Figure 1. All references to location of parts assume the body to be in this erect position. The terms DORSAL and POSTERIOR are both used for the side containing the backbone, and VENTRAL or ANTERIOR for the opposite side. The head end is referred to as CRANIAL and the opposite end as CAUDAL. A part that is above another part is described as SUPERIOR; a part that is below another part is said to be INFERIOR. The term LATERAL refers to the side.

PROXIMAL describes a position near the origin of any part. DISTAL describes a position distant or furthest away from the origin of any part.

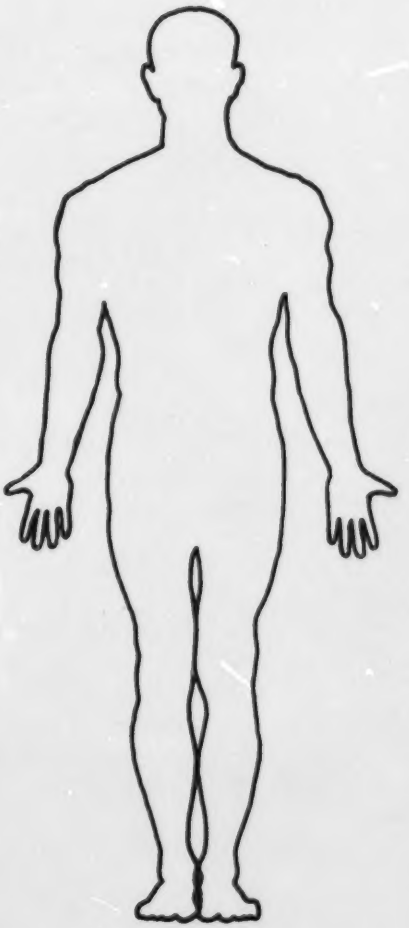

Figure 1.

THE BODY CAVITIES AND CONTENTS

The human body contains five cavities: (1) **the cranial cavity** is the space inside the skull that contains the brain; (2) **the spinal cavity** is the long cylinder-like space inside the spinal column that contains the spinal cord; (3) **the thoracic (chest) cavity** contains the lungs, heart, aorta, and other blood vessels and nerves; (4) **the abdominal cavity,** which is separated from the thoracic cavity by the diaphragm, contains the stomach, liver, gall bladder, small intestine, most of the large intestines (colon and cecum), pancreas, appendix and spleen. The two kidneys lie behind the abdominal cavity, directly below its lining; (5) **the pelvic cavity** contains the reproductive organs, urinary bladder, and the lower part of the intestines. See Figures 2 & 3.

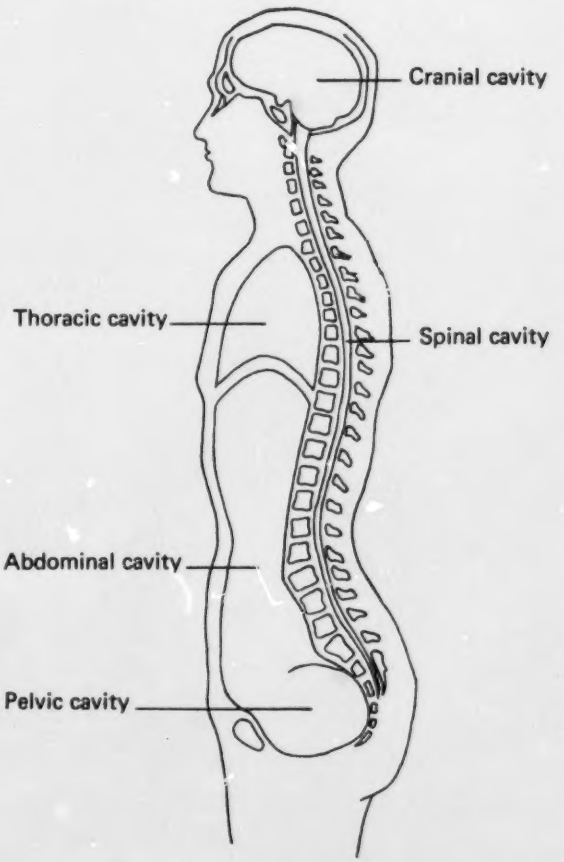

Figure 2. Location of the body cavities

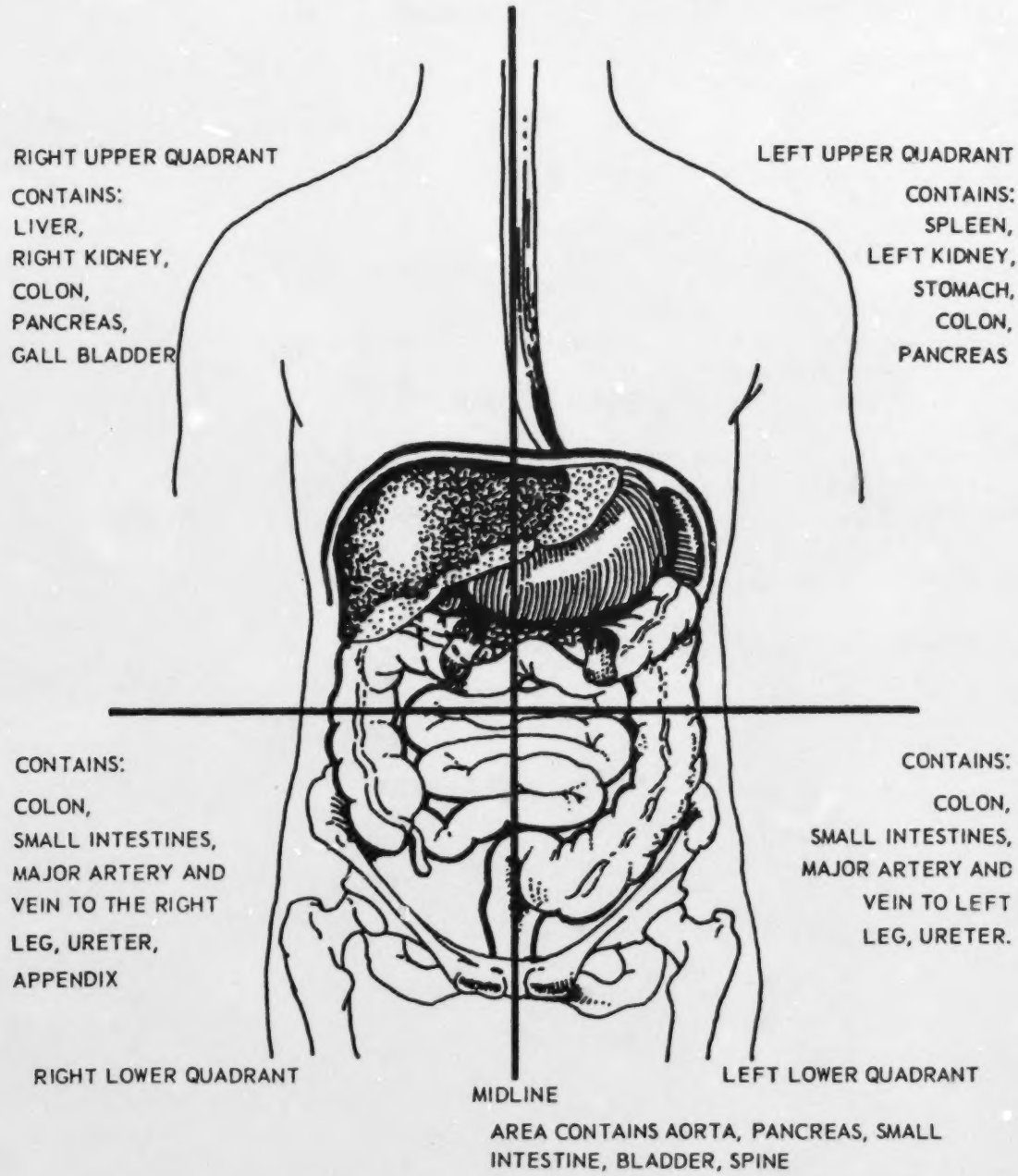

Figure 3. The abdominal cavity showing the contents of each quadrant.

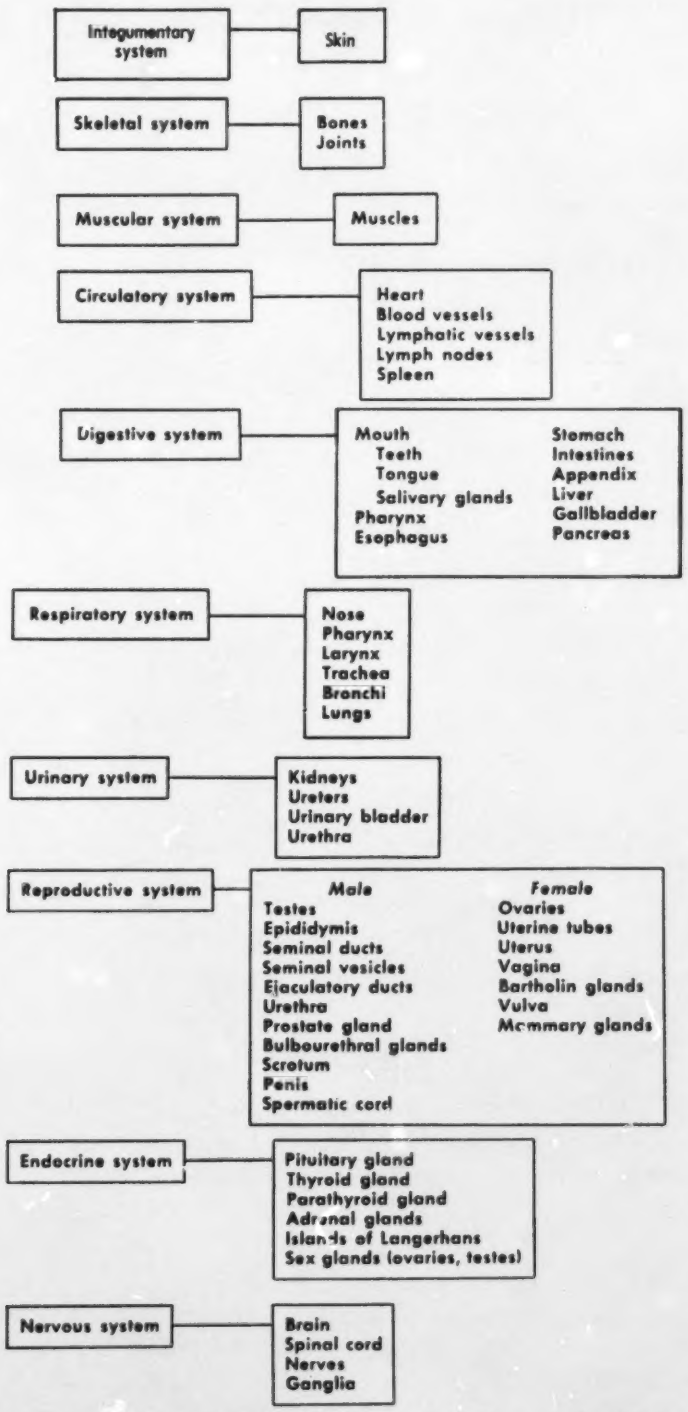

Figure 4. Note: This chart is included to assist in the learning of the 10 body systems and the organs that make up each system.

INTEGUMENTARY SYSTEM

Anatomically, the skin is a layered organ, but as far as the EMT is concerned it functions as a unit or system.

The skin has many functions. It covers the body and protects the deeper tissues from drying, injury, and infectious organisms. It is largely responsible for the regulation of body temperature. This is accomplished in two ways: (1) through evaporation of moisture from its surface in warm weather, and (2) by constricting skin blood vessels in cool weather. The skin contains end organs of many of the sensory nerve fibers by means of which one becomes aware of the environment. The skin consists of two distinct layers: (1) the EPIDERMIS, and (2) the DERMIS and a layer of fatty tissues called the SUBCUTANEOUS layer. See Figure 5. The EPIDERMIS, the outer layer, varies in thickness in different parts of the body, being thickest on the palms of the hands and on the soles of the feet, where the skin is most exposed to friction, and the thinnest on the ventral (ANTERIOR) surface of the trunk and the inner surfaces of the limbs.

The **epidermis** is composed of cells that are waterproof and durable to wear. The outermost layers are made up of dead, hardened cells which are constantly being rubbed off and replaced.

The **dermis,** the second layer, consists of strong elastic tissue. Special structures of the skin are found within the dermis. These are sweat glands, oil glands, hair follicles, blood vessels and specialized nerve endings.

The **subcutaneous** layer is made up of aerolar connective tissue which, except in a few places, contains fat.

A vast network of arteries which supplies the skin can be found in the subcutaneous connective tissues. The capillaries of the skin are so numerous that, when distended, they are capable of holding a large proportion of the blood contained in the body.

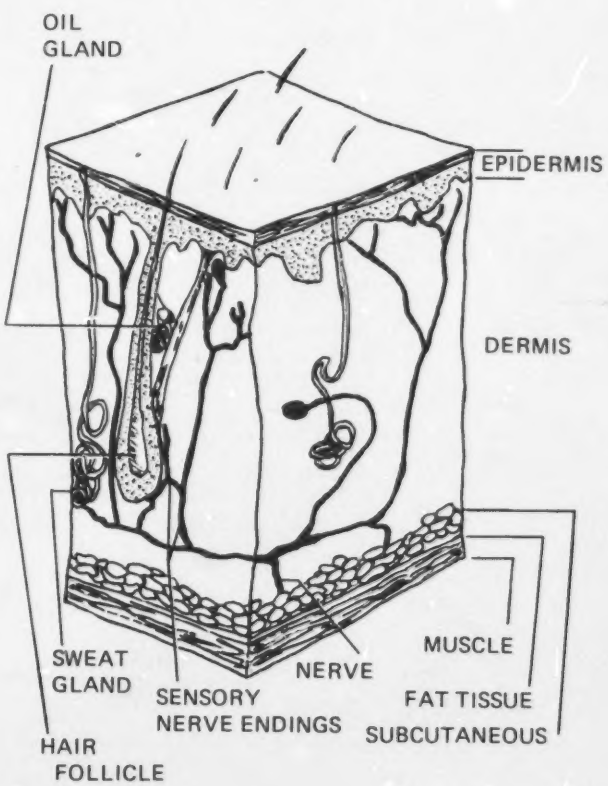

Figure 5. Skin layers

THE SKELETAL SYSTEM

The adult human skeleton is composed of 206 bones which can be classified according to shape as long bones, short bones, flat bones and irregular bones. The skeleton forms a strong but flexible framework for the body. It supports and carries the soft parts, protects vital organs from injury, produces red blood cells and most of the white blood cells. It gives attachment to muscles and tendons and forms joints so movements are possible. See Figure 6.

Divisions of the Skeleton

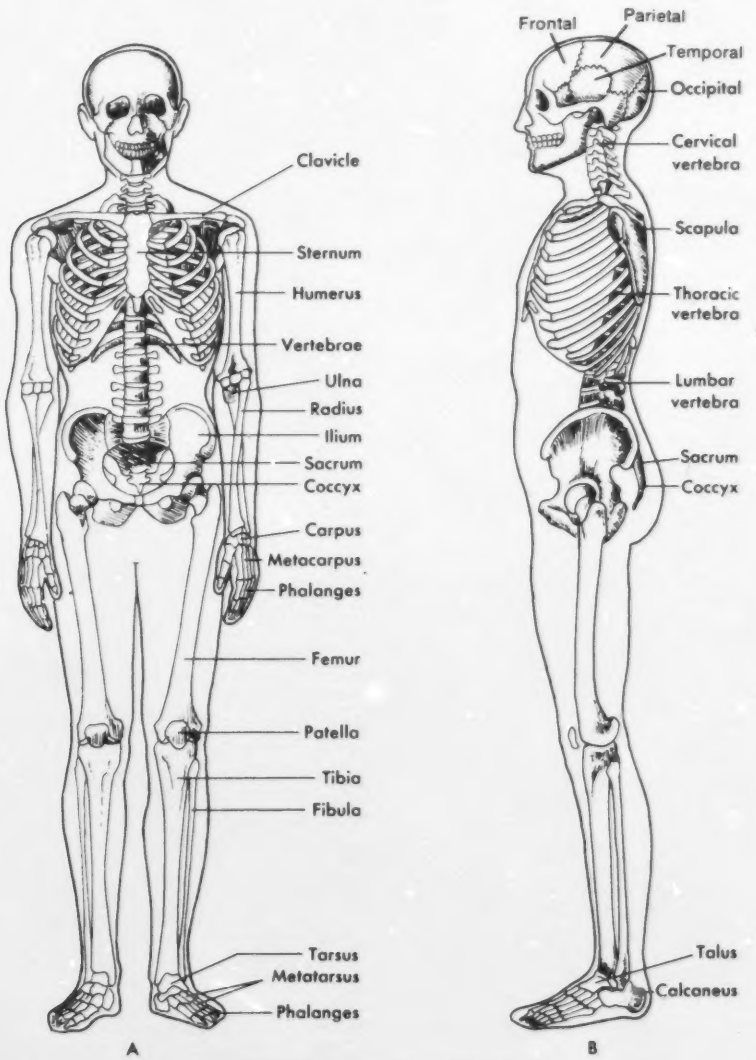

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Figure 6. The human skeleton showing the major bones of the body

DIVISIONS OF THE SKELETON

The skeletal system consists of two major divisions. These major divisions are in turn broken down into several subdivisions.

The first division is referred to as the "axial skeleton" and is subdivided into the bones that make up the skull, spine and thorax. The second division is called the "appendicular skeleton" and consists of the upper extremities and the lower extremities. See Figure 7.

Axial skeleton	*Appendicular skeleton*
Skull	Upper extremities
Cranium	Arms
Face	Hands
Spine	Lower extremities
Vertebrae	Legs
Thorax	Feet
Ribs	
Sternum	
Ear bones	
Hyoid bone	

Figure 7. Main parts of the skeleton

THE SKULL

The skull is composed of 22 bones, eight of which are closely united to form a bony case which encloses the brain; 14 other bones enter into the formation of the face. The only movable bone in the head is the mandible or lower jaw. See Figure 8.

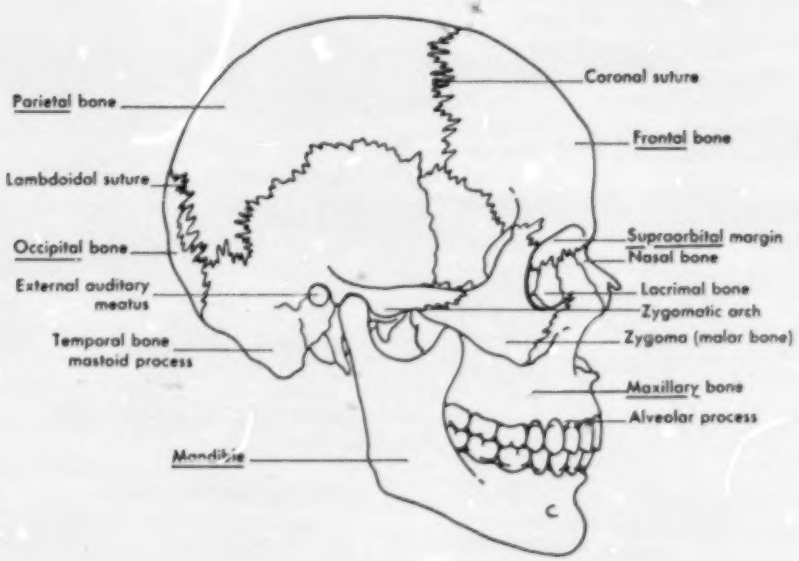

Figure 8. Side view of the skull

THE SPINE (VERTEBRAL COLUMN)

The spine consists of a series of separate bones called vertebrae which are connected in such a way that they form a flexible, curved rod. The curved shape of the spine makes it exceptionally strong.

The sections of the spine are referred to as regions, such as the top seven vertebrae which are called the cervical region; the next 12 vertebrae, the thoracic region; and below that, the five vertebrae of the lumbar region. The five bones of the pelvic region are fused into one bone called the sacrum, and finally, the four bones forming the coccyx or tail bone. See Figure 9.

The spine, by necessity, needs to be very strong for it supports the head at the top. It also supports the ribs and internal organs which are suspended in front and the hips and legs which are attached to its lower section.

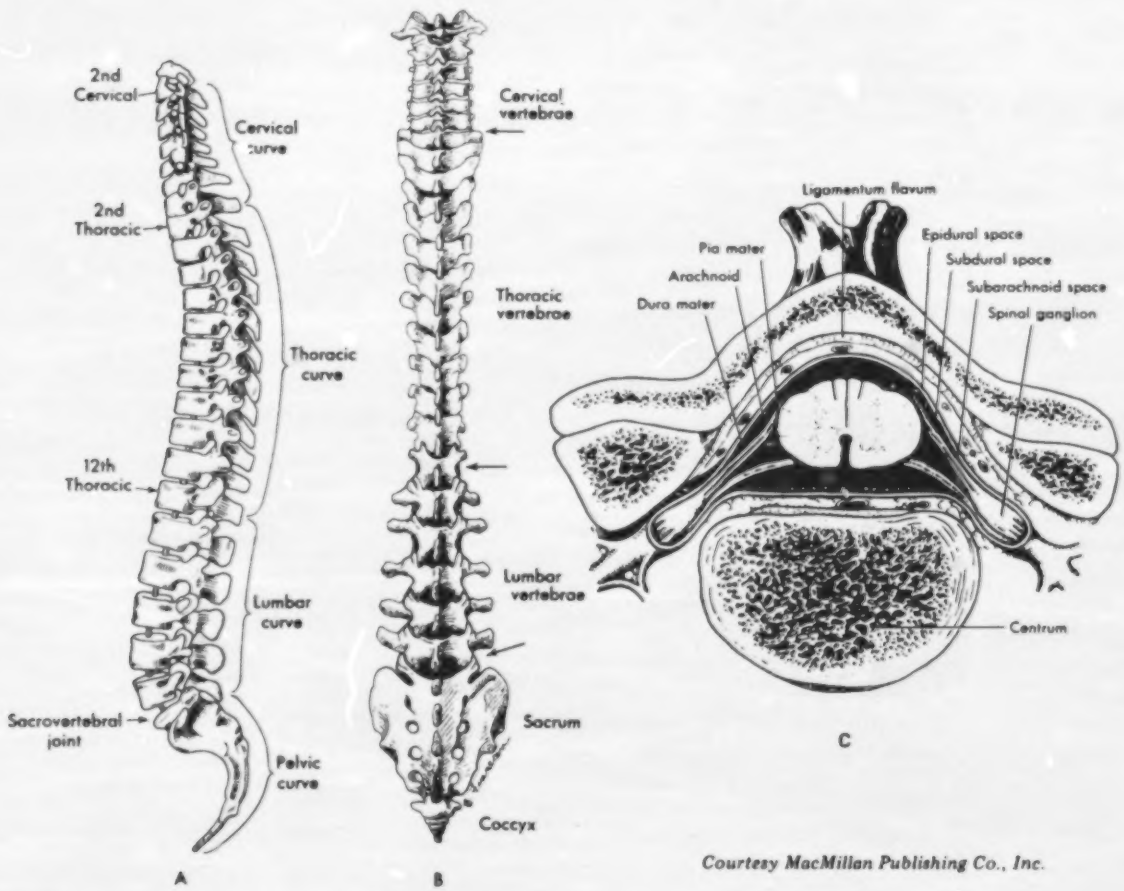

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Figure 9. A - Spinal column left lateral view
B - Spinal column, dorsal view
C - Section of spinal column and vertebrae

THE THORAX (CHEST)

The thorax or chest is made up of 12 pairs of ribs which are attached to the 12 vertebrae of the thoracic spine.

The upper seven pairs are attached to the sternum with individual cartilages and are often called true ribs. The next three pairs of ribs are attached to the sternum by a common cartilage; and the lowest two pairs, which do not attach in front at all, are called floating ribs.

The ribs are attached to the spinal column in such a way as to provide true (or movable) joints. By various muscle action, the ribs are permitted to be drawn in or out. This action makes possible the mechanism of breathing.

THE PELVIS

The pelvis is a basin-shaped, bony structure attached to the two lower sections of the spinal column (sacrum and coccyx). The two largest bones of the pelvis are the broad wing-shaped bones (ilium) usually referred to as the hipbones. The pelvis contains the sockets into which the thigh bones (femur) fit to form the ball-and-socket joint of the hip.

THE UPPER EXTREMITIES

Each upper extremity consists of 32 bones: the collarbone (clavicle), the shoulder blade (scapula), the arm bone (humerus), the two bones of the forearm (radius, thumb side and the ulna, little finger side), the eight bones of the wrist (carpals), the five bones of the hand (metacarpals), and the 14 bones of the fingers (phalanges).

THE LOWER EXTREMITIES

Each lower extremity consists of 30 bones: the thigh bone (femur), the kneecap (patella), the two bones of the leg (tibia or shinbone, and the fibula), the seven bones of the ankle (tarsal bones), five bones of the foot (metatarsals), and the 14 bones of the toes (phalanges).

Both the upper and lower extremities can perform many movements. This many boned framework is connected by movable joints.

JOINTS

Where two or more bones come together, they form a joint. The ends of bones forming joints are covered by cartilage. In a free-moving joint there is a membrane between the cartilage covering the ends of the bones that secretes a fluid to keep the joint lubricated. See Figure 10. The bones forming a joint are held in place by strong ligaments and bands of fibrous tissue. A sac or capsule encloses a free-moving joint. Some joints, such as those in the skull, are immovable. A few joints (such as the vertebrae) allow only slight movement, but the majority of joints allow movement in many directions.

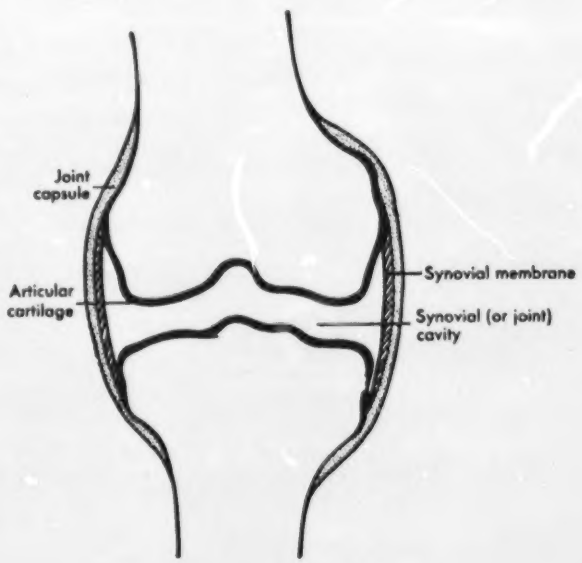


Figure 10. Structure of a freely movable joint

Name	*Number*	*Description*
Cranial bones		
Frontal	1	Forehead bone; also forms front part of floor of cranium and most of upper part of eye sockets; cavity inside bone above upper margins of eye sockets (orbits) called *frontal sinus;* lined with mucous membrane
Parietal	2	Form bulging topsides of cranium
Temporal	2	Form lower sides of cranium; contain *middle and inner ear structures; mastoid sinuses* are mucous-lined spaces in *mastoid process,* the protuberance behind ear; *external auditory canal* is tube into temporal bone
Occipital	1	Forms back of skull; spinal cord enters cranium through large hole *(foramen magnum)* in occipital bone
Sphenoid	1	Forms central part of floor of cranium; pituitary gland located in small depression in sphenoid called *Turk's saddle* or sella turcica
Ethmoid	1	Complicated bone that helps form floor of cranium, side walls and roof of nose and part of its middle partition (nasal septum), and part of orbit; contains honeycomb-like spaces, the *ethmoid sinuses; superior and middle turbinate bones* (conchae) are projections of ethmoid bone; they form "ledges" along side wall of each nasal cavity
Face bones		
Nasal	2	Small bones that form upper part of bridge of nose
Maxillary	2	Upper jawbones; also help form roof of mouth, floor, and side walls of nose and floor of orbit; large cavity in maxillary bone is *maxillary sinus*
Zygoma (malar)	2	Cheek bones; also help form orbit
Mandible	1	Lower jawbone
Lacrimal	2	Small bone; helps form medial wall of eye socket and side wall of nasal cavity
Palatine	2	Form back part of roof of mouth and floor and side walls of nose and part of floor of orbit
Inferior turbinate	2	Form curved "ledge" along inside of side wall of nose, below middle turbinate
Vomer	1	Forms lower, back part of nasal septum
Ear bones		
Malleus	2	Tiny bones in middle ear cavity in temporal bone; name, malleus, means hammer, shape of bone
Incus	2	Incus means anvil, shape of bone
Stapes	2	Stapes means stirrups, shape of bone
Hyoid bone	1	U-shaped bone in neck at base of tongue
Vertebral column		
Cervical vertebrae	7	Upper seven vertebrae, in neck region; first cervical vertebra called *atlas;* second called *axis*
Thoracic vertebrae	12	Next twelve vertebrae; ribs attach to these
Lumbar vertebrae	5	Next five vertebrae; those in "small" of back
Sacrum	1	In child, five separate vertebrae; in adult, fused into one
Coccyx	1	In child, three to five separate vertebrae; in adult, fused into one

Figure 11. Bones of the skeleton - This chart is provided to assist those who are interested in the proper names and locations of the complete skeleton.

Name	*Number*	*Description*
Thorax		
True ribs	14	Upper seven pairs; attached to sternum by way of *costal cartilages*
False ribs	10	Lower five pairs; lowest two pairs do not attach to sternum, therefore, called *floating ribs;* next three pairs attach to sternum by way of costal cartilage of seventh ribs
Sternum	1	Breast bone; shaped like a dagger; piece of cartilage at lower end of bone called *xiphoid process*
Upper extremities		
Clavicle	2	Collar bones; only joints between shoulder girdle and axial skeleton are those between each clavicle and sternum
Scapula	2	Shoulder bones; scapula plus clavicle forms shoulder girdle; *acromion process*—tip of shoulder that forms joint with clavicle; *glenoid cavity*—arm socket
Humerus	2	Upper arm bone
Radius	2	Bone on thumb side of lower arm
Ulna	2	Bone on little finger side of lower arm; *olecranon process*—projection of ulna known as the elbow or "funny bone"
Carpal bones	16	Irregular bones at upper end of hand; anatomical wrist
Metacarpals	10	Form framework of palm of hand
Phalanges	28	Finger bones; three in each finger, two in each thumb
Lower extremities		
Pelvic bones	2	Hip bones; *ilium*—upper, flaring part of pelvic bone; *ischium*—lower, back part; *pubic bone*—lower, front part; acetabulum—hip socket; *symphysis pubis*—joint in midline between two pubic bones; pelvic inlet—opening into *true pelvis*, or pelvic cavity; if pelvic inlet is misshapen or too small, infant skull cannot enter true pelvis for natural birth
Femur	2	Thigh or upper leg bones; *head of femur*—ball-shaped upper end of bone; fits into acetabulum
Patella	2	Kneecap
Tibia	2	Shin bone; *medial malleolus*—rounded projection at lower end of tibia commonly called inner ankle bone
Fibula	2	Long slender bone of lateral side of lower leg; *lateral malleolus*—rounded projection at lower end of fibula commonly called outer ankle bone
Tarsal bones	14	Form heel and back part of foot; anatomical ankle
Metatarsals	10	Form part of foot to which toes attach; tarsal and metatarsal bones so arranged that they form three arches in foot: *the inner longitudinal arch* and the *outer longitudinal arch*, both of which extend from front to back of foot, and transverse or *metatarsal arch* that extends across foot
Phalanges	28	Toe bones; three in each toe, except great toes, where there are two
Total	206	

Figure 11. Bones of the skeleton (Continued)

THE MUSCULAR SYSTEM

Muscles are made up of a special tissue which responds to nerve impulses making it possible to move the different parts of the body.

There are three major types of muscles:

1. **Skeletal** muscles.These muscles are attached to bones and permit voluntary movement. They are the longest of all muscle fibers. See figure 12.
2. **Smooth** muscles. These muscles are smooth and make up the intestines. These shorter than skeletal muscles and their action is involuntary. See Figure 13.
3. **Cardiac** muscles. The fibers of these muscles seem to branch into each other and are involuntary in action. The heart is the only organ that has the branching type muscle. See Figure 14.

Muscles permit movement, maintain posture, and produce heat. To produce movement the muscles are attached, usually to two bones. As the muscles shorten or contract, they pull the bones closer together.The muscles are attached to the bones either directly or by strong ends of fibrous tissue called tendons. All movements are controlled by the brain through impulses to the nerves onto any muscle or group of muscles which it wishes to call into action.

The contraction of skeletal muscles produces heat that maintains normal body temperature. This can be quite evident when a person performs strenuous exercise or, when very cold, one starts to shiver.

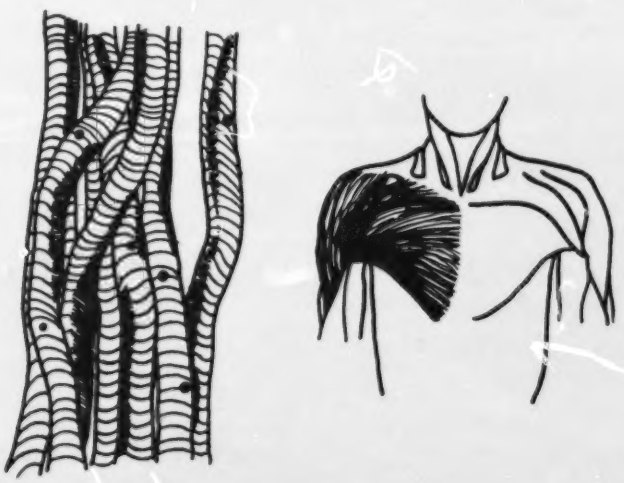


Figure 12. Skeletal muscle—The left diagram shows the long appearance of the muscle tissue, and at the right their attachment to a part of the body.

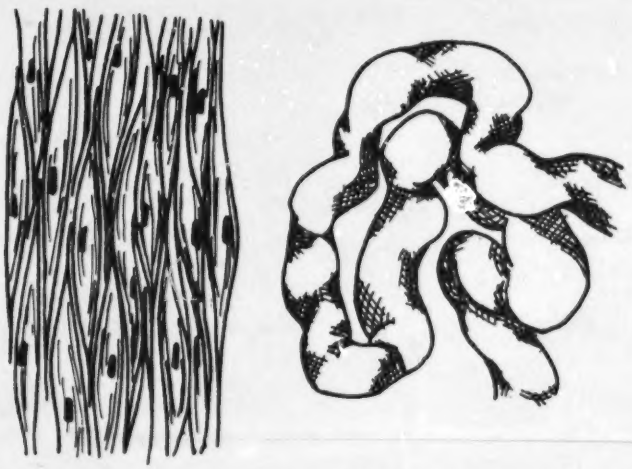


Figure 13. Smooth muscle - The left diagram shows the muscle tissue magnified. Smooth muscles are shorter than skeletal muscles. At right is a section of the intestines that contain smooth muscle.

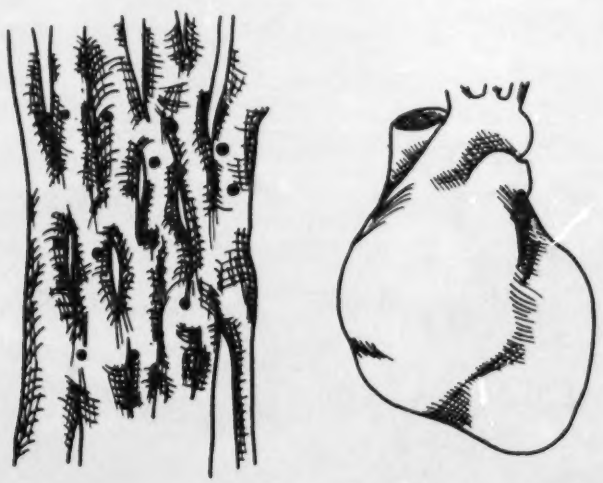


Figure 14. Cardiac muscle - The left diagram shows the cardiac muscle tissue magnified. Note how the fibers branch into each other. At the right is the heart, the only organ that has this type of "branching" muscle.

Muscle tone and strength maintains posture. If back muscles are weakened, the individual may have a slumped appearance. If neck muscles become unable to function, the head would droop forward.

Muscles depend on the work of many other systems in order to do their work. They depend upon the respiratory, circulatory and digestive systems, as well as the nervous and skeletal systems.

Part moved	*Flexors*	*Extensors*	*Abductors*	*Adductors*
Upper arm	Pectoralis major	Latissimus dorsi	Deltoid	Pectoralis major and latissimus dorsi contracting together
Lower arm	Biceps brachii	Triceps brachii	None	None
Thigh	Iliopsoas	Gluteus maximus	Gluteus medius and minimus	Adductor group
Lower leg	Hamstrings	Quadriceps femoris group	None	None
Foot	Tibialis anterior	Gastrocnemius soleus		
Trunk	Iliopsoas and rectus femoris	Erector spinae (sacrospinalis)		

Figure 15. Muscles grouped according to their functions

Muscle	*Function*	*Insertion*	*Origin*
Pectoralis major	Flexes *upper arm* Helps adduct *upper arm*	Humerus	Sternum Clavicle Upper rib cartilages
Latissimus dorsi	Extends *upper arm* Helps adduct *upper arm*	Humerus	Vertebrae Ilium
Deltoid	Abducts *upper arm*	Humerus	Clavicle Scapula
Biceps brachii	Flexes *lower arm*	Radius	Scapula
Triceps brachii	Extends *lower arm*	Ulna	Scapula Humerus
Iliopsoas	Flexes *trunk*	Ilium Vertebrae	Femur
Iliopsoas	Flexes *thigh*	Femur	Ilium Vertebrae
Gluteus maximus	Extends *thigh*	Femur	Ilium Sacrum Coccyx
Gluteus medius	Abducts *thigh*	Femur	Ilium
Gluteus minimus	Abducts *thigh*	Femur	Ilium
Adductors	Adduct *thigh*	Femur	Pubic bone
Hamstring group	Flexes *lower leg* Helps extend *thigh*	Tibia Fibula	Ischium Femur
Quadriceps femoris group, including rectus femoris	Extends *lower leg* Helps *flex thigh*	Tibia	Ilium Femur

Figure 16. The functions, origins and insertions of muscle

THE NERVOUS SYSTEM

The various parts of the body and the organs controlling the body functions are kept in touch with each other by the nervous system. The nervous system consists of two separate but interconnected and coordinated systems: (1) the central nervous system, sometimes called the cerebrospinal system, and (2) the autonomic nervous system which consists of the para-sympathetic and the sympathetic nervous system.

The central nervous (cerebrospinal) system is composed of the brain and spinal cord. The brain is a collection of nerve centers. Each center acts as a central station for some part of the body, much like a central telephone station with trunk lines or nerves connecting the parts of the body with their particular centers. Leaving the brain, these trunk nerves are bundled together into the spinal cord. As the spinal cord passes down through the spinal cavity, branches are given off to all parts and organs of the body.

Nature has provided protection for the delicate nervous system by enclosing the brain in a bony case (the skull) and the spinal cord by enclosing it in the center of the body vertebrae. Injuries to the head, especially when the skull is fractured, may cause serious damage to the delicate nerve tissues of the brain. Likewise, fractures of the backbone or spine may cause the spinal cord to be cut or pinched so severely as to result in paralysis below the point of injury. Cutting or severe pinching of a trunk nerve after it has left the spinal cord, as in the arm or leg, will cause paralysis below the point of injury. The nerves entering and leaving the spinal cord are mainly of two types—**sensory nerves** entering the cord, which convey impressions of sensations, such as heat, cold, touch, and pain from different parts of the body to the brain; and **motor nerves,** leaving the spinal cord, conveying impulses from the brain to the muscles causing movement.

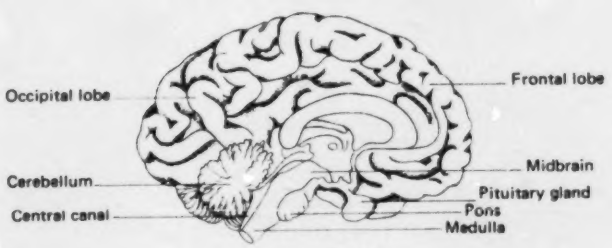


Figure 17. Cross section of the human brain

Courtesy MacMillan Publishing Co., Inc.

Figure 18. Diagram illustrating the brain, spinal cord, and spinal nerves

The autonomic nervous system consists of a series of nerve centers, called ganglions, in the chest and abdominal cavity along the spinal column. Each of these ganglions or nerve centers, although interconnected to the central nervous system, presides over and controls vital organs and vital functions. This system is not under control of the will, but through it involuntary muscles are stimulated to act alike during periods when we are awake and when we are asleep. Thus, the heart beats, we breathe, blood pressure is maintained, we digest our food, and excretory organs function independently of any effort on our part.

The nervous system plays a very important role in conditions of shock that result from injuries or exposure.

THE BRAIN

The three most prominent parts of the brain are the cerebrum, the cerebellum, and medulla. The cerebrum is the largest part of the human brain. Its interior is composed mostly of nerve fibers arranged in bundles called tracts. The function of the cerebrum is to develop mental processes of all types, including voluntary control of movements and consciousness.

The cerebellum is the second largest part of the human brain. It helps to control muscle contractions so they produce coordinated movements to maintain our balance and move smoothly.

*Cranial nerve**	*Conducts impulses*	*Functions*
I. Olfactory	From nose to brain	Sense of smell
II. Optic	From eye to brain	Vision
III. Oculomotor	From brain to eye muscles	Eye movements
IV. Trochlear	From brain to external eye muscles	Eye movements
V. Trigeminal (or trifacial)	From skin and mucous membrane of head and from teeth to brain; also from brain to chewing muscles	Sensations of face, scalp, and teeth; chewing movements
VI. Abducens	From brain to external eye muscles	Turning eyes outward
VII. Facial	From taste buds of tongue to brain From brain to face muscles	Sense of taste; contraction of muscles of facial expression
VIII. Auditory (or acoustic)	From ear to brain	Hearing Sense of balance
IX. Glossopharyngeal	From throat and taste buds of tongue to brain; also from brain to throat muscles and salivary glands	Sensations of throat; taste; swallowing movements; secretion of saliva
X. Vagus	From throat, larynx, and organs in thoracic and abdominal cavities to brain; also from brain to muscles of throat and to organs in thoracic and abdominal cavities	Sensations of throat, larynx, etc.; swallowing, peristalsis, heart contractions, etc.
XI. Spinal accessory	From brain to certain shoulder and neck muscles	Shoulder movements; turning movements of head
XII. Hypoglossal	From brain to muscles of tongue	Tongue movements

*The first letters of the words of the following sentence are the first letters of the names of cranial nerves: "On Old Olympus' Tiny Tops A Finn and German Viewed Some Hops." Many generations of students have used this or a similar sentence to help them remember the names of cranial nerves.

Figure 19. The cranial nerves and their functions

Structure	*Parasympathetic control*	*Sympathetic control*
Heart muscle	Slower heartbeat	Faster heartbeat
Most blood vessels	None	Constricted
Blood vessels in skeletal muscles	None	Dilated
Digestive tract	Increased peristalsis and increased secretion	Decreased peristalsis; decreased secretion
Adrenal glands	Decreased epinephrine secretion	Increased epinephrine secretion
Sweat glands	None	Increased sweat secretion

Figure 20. The functions of the autonomic nervous system

The medulla is the lowest part of the brain. Actually, it is an enlarged extension of the spinal cord in the cranial cavity. The medulla must be considered a most vital part of the brain for it controls the heartbeat, blood pressure, and respiration. See Figures 17 through 20.

THE RESPIRATORY SYSTEM

The human body can be deprived of food and water for extended periods, but it must have a continuous supply of oxygen if expected to survive. Every body cell requires oxygen to live and to function properly. During the act of respiration, air is taken into the lungs during inspiration and forced out of the lungs during expiration.

The respiratory system consists of the nose and mouth, pharynx, larynx, trachea, bronchi, and lungs. In addition, there are the respiratory muscles (the diaphragm) and the breathing control center in the brain.

As the inhaled air passes through the nose and mouth, it is warmed and, by means of the hairs in the nose and the moist mucous membranes, much of the dust in the air is filtered out.

The pharynx (throat) is a continuation of the nose and mouth; at its lower end are two openings, one in front of the other. The one in front is called the trachea (windpipe) and leads to the lungs. The one behind is called the esophagus (food pipe) and leads to the stomach.

At the top of the trachea is a flap called the epiglottis which closes over the trachea during the act of swallowing to prevent food or liquid from entering it.

The larynx or voice box is located just below the pharynx. This area is commonly known as the "Adam's Apple." The voice box contains two short fibrous bands called vocal cords. Muscles attached to these cords can cause them to be short and tight or long and relaxed, which affects the tonal changes in your voice.

The trachea extends into the chest cavity and divides into the right and left bronchi, one passing to the right lung and the other to the left lung. Each bronchus enters the lung and divides and subdivides into many branches known as bronchial tubes. The bronchial tubes continue to subdivide and branch off into smaller branches or air sacs called the alveoli. The alveoli are shaped like miniature clusters of grapes. It is here that the air is brought into contact with the minute capillaries of the lungs and the exchange of carbon dioxide and oxygen takes place. See Figure 21.

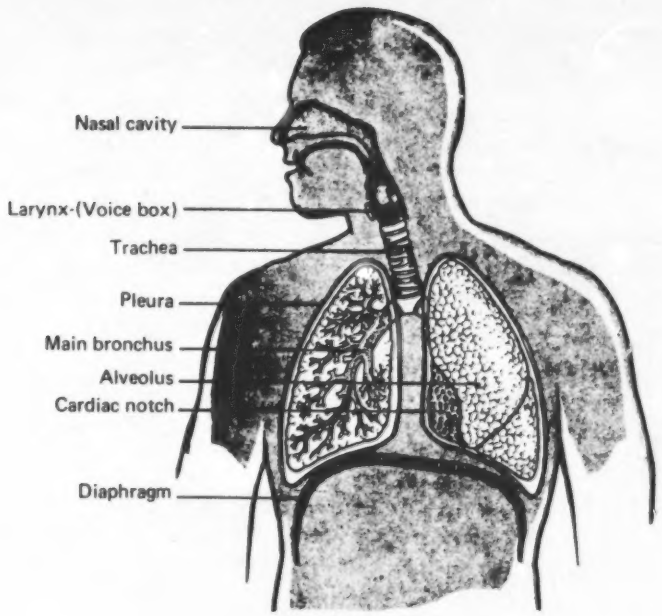


Figure 21. The organs of the respiratory system

THE LUNGS

The lungs are two cone-shaped bodies that are soft, spongy, and elastic. The outside of each lung is covered by a closed sac called the pleura. The inner part of the lungs communicates freely with the outside air through the windpipe. The outside of the lungs is protected from air pressure by the walls of the chest cavity, creating a lessened pressure within the enveloping lung sac. The air pressure within the lungs expands them until they fill almost the entire chest cavity.

If any air gets through the chest wall, or if the lung is punctured so air from the outside can communicate with the pleural sac, the lungs shrink because the air pressure is equalized on the outside and inside of the chest cavity.

After subdividing into very small branches the bronchial tubes end in a group of air cells resembling a bunch of grapes, except that they are many times smaller. Around each air cell, which has very thin walls, is a fine network of small blood vessels or capillaries. The blood in these capillaries gives up the carbon dioxide and other waste matter brought from tissue activity all over the body, through the thin cell wall and in exchange takes on a supply of oxygen from the air breathed into the cells. The discarded carbon dioxide and waste matter pass from the cells in air breathed out of the lungs.

RESPIRATION AND THE MECHANICS OF BREATHING

Breathing is an act over which we exert little control. It occurs in the healthy adult about 12-20 times a minute when at rest, but the rate per minute may be increased by exercise, labor, and a number of other causes. The amount of air entering and leaving the lungs during each respiration varies, as does the rate of breathing, according to whether the person is at rest or engaged in work or exercise. At rest, adults

breathe 25 to 30 cubic inches of air per respiration, whereas during strenuous effort the amount may be increased several times.

Breathing consists of two separate acts: inspiration, an enlargement of the chest cavity with a lowering of the pressure within the cavity, during which air is drawn into the lungs; and expiration, a lessening of the chest cavity and increasing of the pressure within the cavity, during which air is driven out of the lungs. In inspiration, which is chiefly a muscular act, the ribs are raised and the arch of the diaphragm falls and becomes flattened, thus increasing the capacity of the chest cavity, and tending to produce a vacuum causing air to enter. In expiration, an act performed with slight muscular action, the ribs fall to their normal position and the arch of the diaphragm rises, lessening the capacity of the chest cavity; air is forced out. See Figure 22.

As all living tissues of the body depend on the oxygen carried by the blood for life, interference with breathing that reduces fresh supplies of oxygen to the blood produces a condition of oxygen want or asphyxia throughout the entire body.

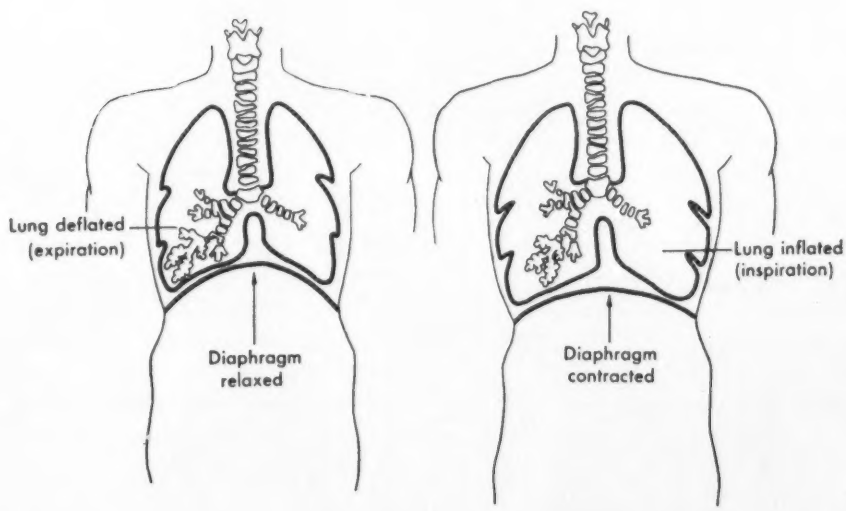


Figure 22. The difference in size of the chest cavity and lungs during expiration and inspiration

THE CIRCULATORY SYSTEM

INTRODUCTION

The circulatory system consists of the heart, the arteries, the veins and the capillaries. It is most interesting to note that this system contains approximately 60,000 miles of tubing through which it carries blood to all parts of the body. Regardless of the forces of gravity and the many thousands of routes, circulation is constantly maintained by the arteries carrying blood away from the heart and the veins returning blood to the heart. The arteries branch into smaller arterioles which in turn branch into millions of minute capillaries. The capillaries unite with veins and return the blood to the heart. Before the blood is returned to the body, it circulates through the lungs where it deposits carbon dioxide and replenishes itself with oxygen. This entire circulatory cycle is complete in approximately 1-1/4 minutes.

THE HEART

The heart is a hollow muscular organ, approximately the size of your fist, located beneath the lower half of the sternum, between the two lungs, and just above the diaphragm. The heart is divided into a right and left side, between which there is no direct connection. Each side is further divided into an upper or receiving chamber (atrium) and the lower or pumping chambers (ventricles). Between each of the chambers there is a one-way valve that permits the blood to flow in one direction. In the normal adult, with the body at rest, the heart contracts at the normal rate of 60-100 times per minute. See Figure 23.

THE MECHANICS OF CIRCULATION

The circulatory system actually consists of two systems, **pulmonary circulation** and **systemic circulation.** With each contraction of the heart, blood is forced through each of these systems from the ventricles; likewise with relaxation of the heart, blood fills the atria.

Pulmonary Circulation — Blood is returned to the heart by two large veins that empty into the right atrium; from here it passes through a one-way valve into the right ventricle. Due to contraction or pumping action, the blood is forced through the pulmonary artery to the lungs. In the lungs the exchange of carbon dioxide and other gases for oxygen takes place. The blood, now rich in oxygen, is returned to the left atrium through the pulmonary veins.

Systemic Circulation — From the left atrium the oxygenated blood passes through a one-way valve into the left ventricle. The left ventricle provides the necessary strong pumping action that forces the blood through the aorta. The aorta (the main artery of the body) subdivides to distribute blood to all parts of the body.

BLOOD

The blood consists of a fluid called plasma and red and white cells. In one cubic millimeter of blood (one drop) there are approximately 5 million red cells and approximately 7,000 white cells. **Red cells** live only a few weeks and are continuously being replaced by new ones produced by red marrow of certain bones and the spleen. **White blood cells** serve in combating germs and in the removal of other harmful bodies. They do this by actually absorbing the harmful organisms into their own cells. White cells are produced by bone marrow, the spleen and the lymph nodes.

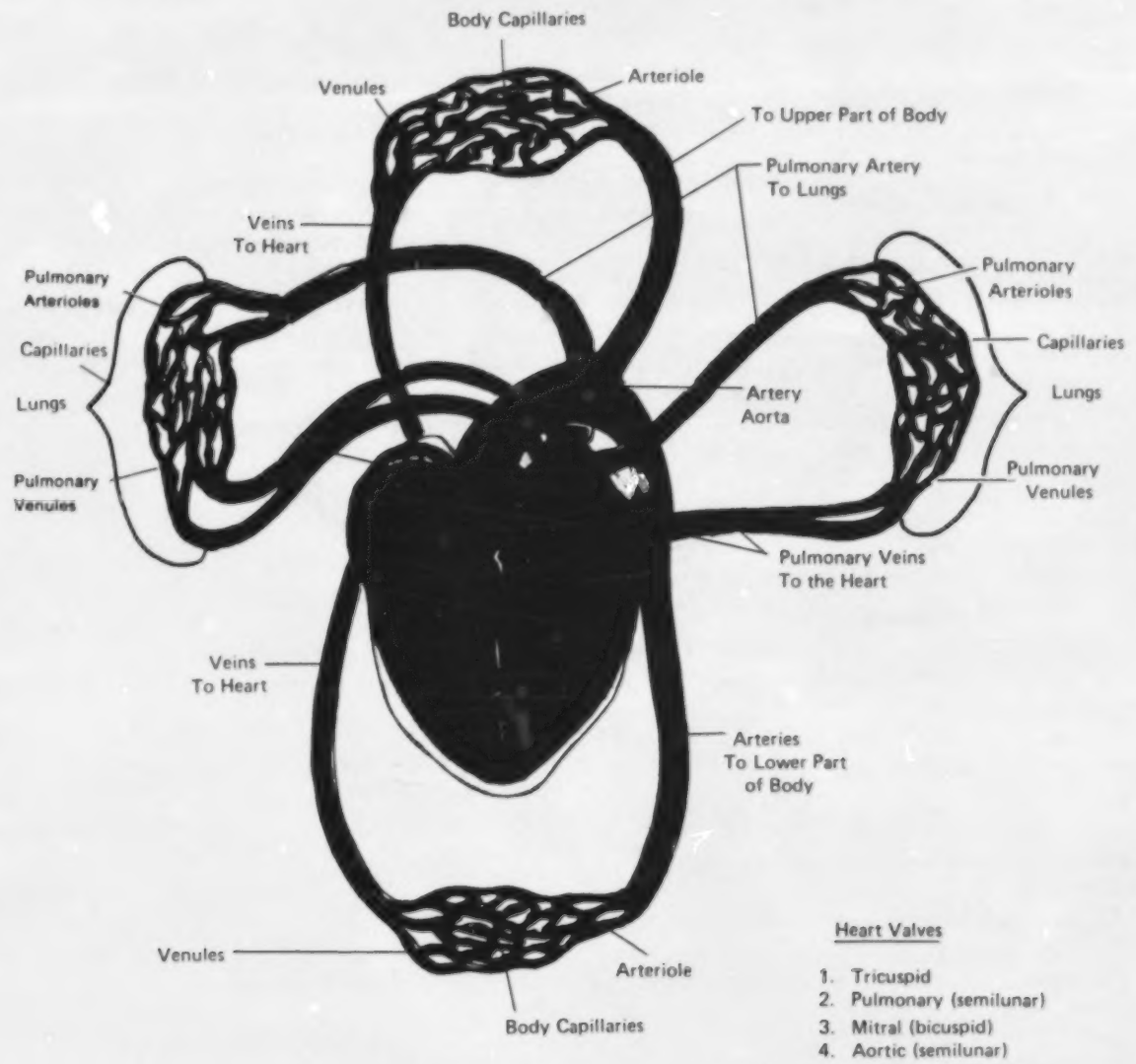


Figure 23. Circulation of blood through the heart and body

BLOOD VOLUME AND BLOOD PRESSURE

One-twelfth to one-fifteenth of the body weight is blood. The circulatory system of a normal, average person, weighing 150 pounds, will contain 10 to 12 pints of blood.

Blood pressure is that pressure in the arteries created and maintained by the contraction or beating of the heart. A sufficient force is required to push the blood through the thousands of miles of blood vessels that make up the circulatory system.

PULSE

The pulse beat can be felt at various points on the body. Its beat corresponds to the con-

traction or beating of the heart. In the average adult the rate of beating is 60-100 times per minute. In children a normal pulse rate is much faster, reaching up to 110 beats per minute.

In feeling for the pulse of a sick or injured person, you must make an estimate of the following:

a) The speed: Is it fast? Slow? Normal?
b) The strength: Is it normal? Strong? Weak?
c) The rhythm: Is it regular? Irregular?

THE CLOTTING MECHANISM

Nature provides a clotting mechanism that will physically plug a lacerated or severed blood vessel and stop bleeding that otherwise might prove to be fatal. This mechanism goes into action whenever blood flows over or through a rough spot in the vessel lining. Almost immediately **platelets** floating in the blood break up and release a substance called **thromboplastin** which unites with **prothrombin** (a protein in the blood) and calcium to form **thrombin.** It is the thrombin that causes **fibrinogen** (another protein in blood) to gel and become **fibrin.** The fibrin forms a thread-like netting that catches the red blood cells, forming the clot and stopping the flow of blood. See Figure 24.

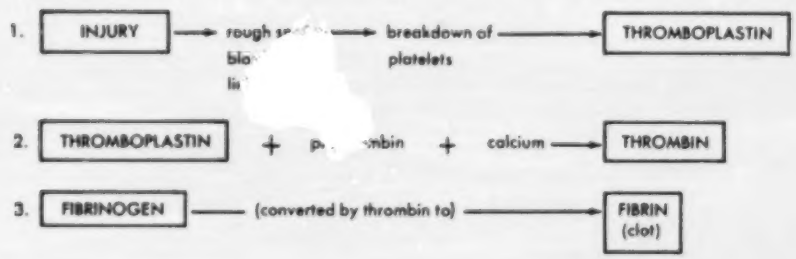


Figure 24. The main steps in blood clotting

LYMPH NODES AND THE SPLEEN

The lymphatic system is a part of the overall circulatory system. The lymph fluids come from the blood and return to the blood. In this circulatory process, injurious particles such as bacteria and other microorganisms are filtered by the lymph nodes from the blood to prevent their further circulation throughout the body. Certain lymph nodes of persons with infections or cancer will swell and exhibit tenderness and pain. See Figure 25.

The spleen is located in the upper left part of the abdominal cavity, just below the diaphragm. Its true functions present much mystery and doubt. However, it is known that it produces blood cells and combats germs and bacteria. It can store up to two cups of blood that can be released very quickly into the circulatory system when needed, such as during vigorous exercise and after severe bleeding.

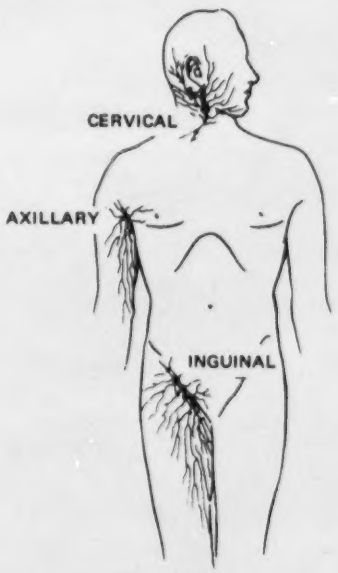


Figure 25. Location of principal lymph nodes

THE DIGESTIVE SYSTEM

The digestive system consists of an open tube beginning at the mouth and extending to its outlet, the anus. This tube connects the organs of digestion that include the mouth, pharynx, esophagus, stomach, small intestines, large intestines, and the anal canal. Accessory digestive organs include the teeth, tongue, salivary glands, liver, gall bladder, pancreas, and the appendix.

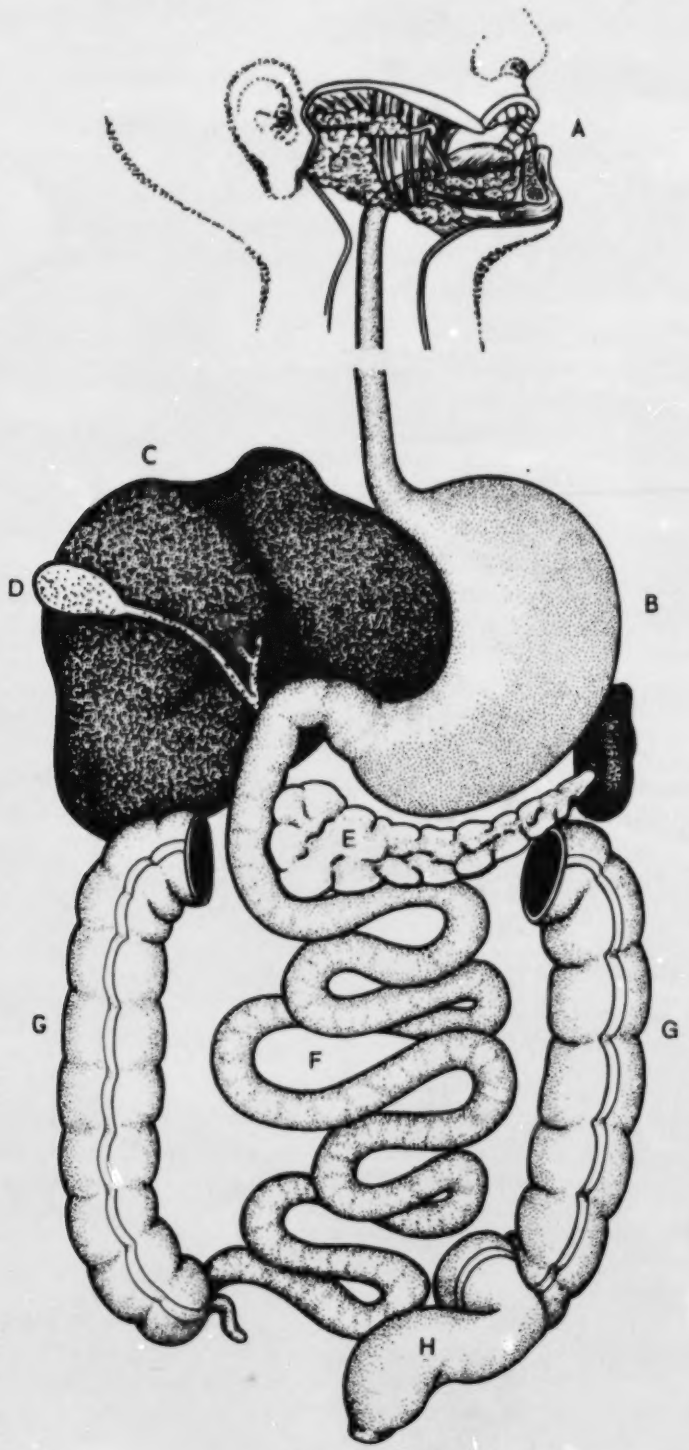
The digestive process comprises the intake of food, both solids and liquids; the preparation of the food mechanically and chemically for absorption of its useful products; and the elimination of waste and useless residue. See Figure 26.

THE STOMACH

After food has been chewed and swallowed, it enters the stomach from the esophagus. The stomach is a pouch-like organ, not much bigger than a large sausage when emptied, but capable of considerable expansion after eating a large meal.

The lower part of the stomach is called the pylorus. The pylorus is a narrow section that connects with the first part of the small intestine (the duodenum). Food is held in the stomach by the pyloric muscle long enough for partial digestion. These muscles stay contracted most of the time to keep the opening to the duodenum closed. They relax at certain intervals when a portion of the food is ready to leave the stomach. The average meal remains in the stomach three to six hours before it is discharged into the duodenum.

Muscle fibers running lengthwise, around, and diagonally in the stomach wall make it one of the strongest abdominal organs. These muscles are capable of breaking food into minute particles and mixing the food thoroughly with the gastric juice. The stomach is lined with mucous membranes that contain thousands of tiny glands that give off the gastric juice and hydrochloric acid. When the stomach is empty, its lining lies in folds called rugae.



A. The mouth. Here the food is broken up into small particles (mastication) and mixed with saliva, which moistens the food for swallowing and begins the digestion of starch.

B. The stomach serves as a storehouse for food immediately after it is eaten. It produces an enzyme, pepsin, which, in the presence of hydrochloric acid, digests proteins. Mechanically it breaks up food into small particles and mixes it with gastric juice.

C. The liver produces bile, which neutralizes the acid food coming from the stomach, helps emulsify fats, and stimulates the action of the intestine.

D. The gall bladder serves as a place of concentration and storage of liver bile. Liver bile aids in the digestive process.

E. The pancreas produces important enzymes for the digestion of proteins, carbohydrates and fats. Its secretion enters the intestine with the bile.

F. The small intestine (about 20 ft. long). Here the food is pushed slowly along and is kept thoroughly mixed with digestive juices by peristalsis. Digestion is completed here and most of the absorption takes place.

G. In the large intestine absorption of water takes place and bacteria act on the food mass, further digesting carbohydrates.

H. In the rectum the waste matter is concentrated for defecation.

Figure 26. The digestive system and organs involved

THE SMALL INTESTINE

The small intestine is so named because it is smaller in diameter than the large intestine. The length of the small intestine is approximately 20 feet. There are three sections: the duodenum, the jejunum, and the ileum, named in the order in which food passes through them.

The mucous lining of the small intestine contains thousands of minute glands. The intestinal glands give off the intestinal digestive juice. Even though the lining of the intestine appears smooth, it is made up of thousands of microscopic "fingers" that project into the hollow interior of the intestine. Inside these finger-like structures lies a rich network of blood and lymph capillaries that affords faster absorption of food into the blood and lymph.

The involuntary muscle action of the intestinal walls creates the contractions that produce the worm like action which moves food through the intestinal tract.

THE LARGE INTESTINE

The lower part of the digestive tract is formed by the large intestine. It is divided into the following sections: the cecum, ascending colon, transverse colon, descending colon, pelvic (sigmoid) colon, and the rectum. The rectum is approximately seven to eight inches long, and its external opening is called the anus. Two muscles stay contracted to keep the anus closed except during defecation. An involuntary muscle composes the inner anal action, but a voluntary muscle composes the outer. This explains the reason why some victims of stroke or other paralytic conditions lose complete muscle control of the anal area and have "involuntary defecations."

ACCESSORY DIGESTIVE ORGANS

The accessory digestive organs are those that help digest food but do not form part of the digestive tract itself.

The **mouth** serves several purposes. The **teeth** tear food apart, the **tongue** tastes it, the **salivary glands** lubricate the food and, to a slight degree, help digest some starches.

The **liver** is the largest organ in the body. It is located in the upper right-hand section of the abdominal cavity and extends part way to the left side. One of its functions is to secrete bile which is a digestive juice. In addition, the liver helps to keep the amounts of sugar and proteins in the blood at normal levels.

The **gall bladder** is located on the undersurface of the liver. It serves as a place of concentration and storage of liver bile. When fats enter the duodenum, the gall bladder ejects bile into it to aid in the digestive process.

The **pancreas** is located behind the stomach. Some of its cells secrete pancreatic juice. This important digestive juice drains into the duodenum at the same piace that the liver bile enters. Other cells of the pancreas secrete insulin into the blood. Insulin is a hormone necessary for maintaining a normal amount of blood sugar.

The **appendix** is a worm-like tube located off the cecum. It serves no known purpose, but it causes much trouble when its mucous lining becomes inflamed. We are all familiar with this affliction called appendicitis.

DIGESTION

All of the aforementioned organs work together to perform the function called digestion. Basically, digestion is the changing of foods into substances that can be absorbed through the mucous membrane lining of the small intestine, passing them on into the blood and eventually on to all cells of the body. This involves both mechanical and chemical processes.

The **mechanical processes** include chewing, swallowing, and peristalsis. Peristalsis is the rhythmic, wave-like motion of the stomach and intestinal walls that breaks food into minute

particles and mixes them with digestive juices and moves them along the digestive tract.

The **chemical processes** are many. Food molecules too large for absorption are broken down by chemical reactions of the digestive enzymes into smaller molecules which easily pass through the intestinal walls into the blood.

Protein digestion starts in the stomach and is completed in the small intestine. Proteins are the "tissue-building foods."

Carbohydrate digestion takes place mainly in the small intestine. Carbohydrates and fats are the "energy foods."

THE URINARY SYSTEM

The urinary system consists of the kidneys, the ureters, the urinary bladder, and the urethra. These organs form and remove urine from the body. In doing so, they maintain the body's water balance or water chemistry. Among the most principal wastes removed by the urine are substances that co: tain nitrogen. If these were removed, it could build up at an alarming rate and create a dangerous toxic condition.

The kidneys lie behind the abdominal organs, on either side of the vertebral column. The left kidney is usually a little larger than the right kidney and a little farther above the waist.

The blood circulating through the kidneys permits them to filter out water and other dissolved substances. However, due to certain kidney diseases and heart disease, the kidneys may not excrete normal amounts of urine. The normal urine output is a little more than a quart per day.

Perched atop each kidney are the adrenal glands. The adrenals secrete many important hormones and have much to do with the actions and reactions of the body during periods of great psychological pressure.

Urine leaves the kidneys through the ureters. The ureters are thick fibrous tubes that run downward along the muscles covering the spinal column and empty into the urinary bladder.

The urinary bladder is a thick muscular organ located deep in the pelvis. The muscular expansion permits the bladder to hold variable amounts of urine and then to be able to contract to expel the urine. Most people have the urge to urinate when the bladder contains about one-half pint of urine.

The bladder empties itself through the urethra. In women the urethra is about one and one-half inches long, but in men it will be approximately eight inches long. The urethra is the lowest point of the urinary system and the organ that permits the urine to leave the body. See Figure 27.

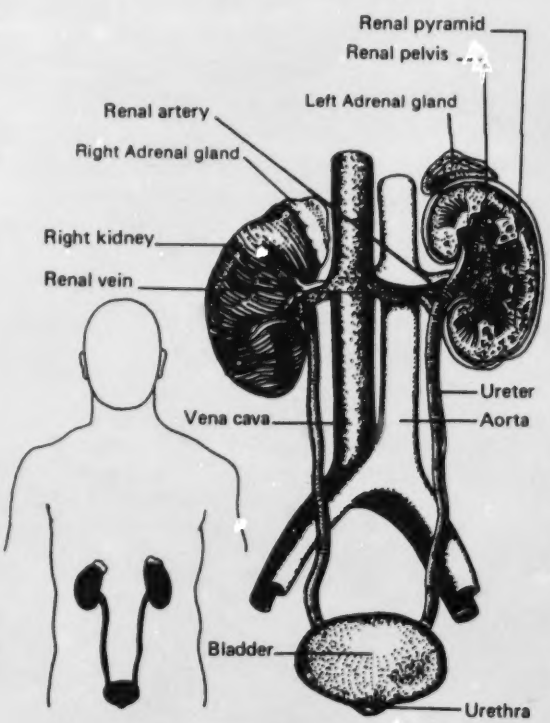


Figure 27. The organs of the urinary system

THE REPRODUCTIVE SYSTEM

The **male reproductive system** consists of four major divisions: (1) the main sex glands, (2) the ducts, (3) accessory sex glands, and (4) the external genitalia.

The main sex glands are the **testicles.** They produce the sperm cells which eventually unite with the female sex cell (ovum). There are millions of sperm cells in each ejaculation, yet only one will succeed in fertilizing the ovum.

The **ducts** begin at the testicle where the sperm enters into a narrow tube which is about 20 feet long, tightly coiled and lies on top of the testicle. Following the diagram, Figure 28, we can trace the path of the semen through the **seminal duct,** the **ejaculatory** duct, and finally the **urethra.**

The **accessory sex glands** are the seminal vesicle, the bulbourethral and the prostate. They secrete a fluid (semen) to carry the sperm through the many ducts to its destination. They also inject an alkaline secretion to the semen to permit the sperm cells to live and remain fertile. Sperm cells survive much longer in an alkaline fluid than in an acid one.

The **external genitals** consist of the **scrotum** and the **penis.** The scrotum is the pouch or sac that contains the testicles. The penis is the male organ that places the sperm within the female. It is made up of a special kind of tissue that contains many small spaces that are usually collapsed. Under sexual stimulation, blood flows into these small spaces, expanding them enough to cause enlargement and rigidity of the organ.

The **female reproductive system** is similar to the male inasmuch as it consists of four major divisions: (1) the main sex glands, (2) the ducts, (3) the accessory glands, and (4) the external genitals.

The main sex glands are the ovaries. They are located in the pelvic cavity and are made up of thousands of little sacs. Within each of these little sacs lies an immature ovum (female sex cell). One ovum matures each month and is ejected into the fallopian tube. This is called ovulation.

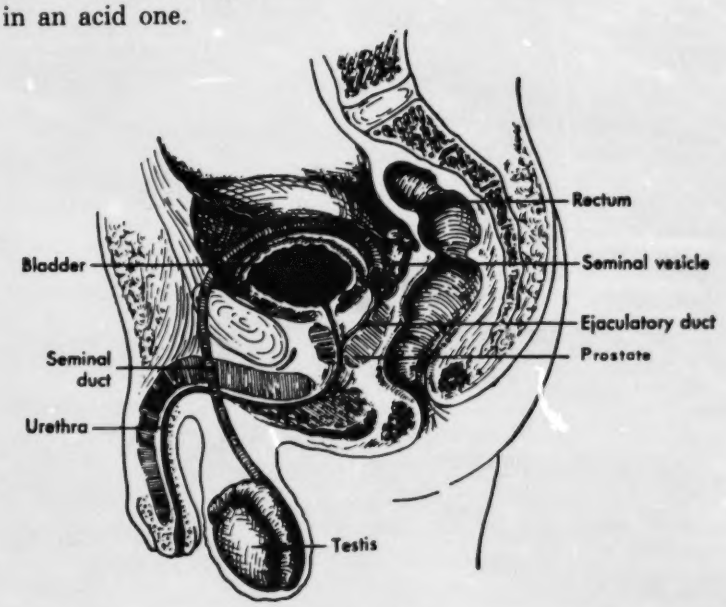


Figure 28. The male pelvis showing the organs of reproduction

The **ducts** consist of the **fallopian tubes,** the **uterus,** and the **vagina.** The fallopian tubes serve as a passage to carry the ovum from the ovary to the uterus. Each tube is approximately four inches long and is connected directly to the uterus, but not to the ovaries. The **uterus** is a muscular pear-shaped organ approximately three inches long, two inches wide and one inch thick. During pregnancy this organ expands and is capable of holding a baby plus a considerable amount of fluid. Following ovulation the ovum passes through the fallopian tube to the uterus. If the ovum is united with the sperm cell, fertilization occurs and the united cells will imbed themselves in the prepared uterine lining to grow into the fetus. However, if fertilization does not occur, the uterus will cleanse itself of the unfertilized ovum and the prepared lining through an act called menstruation, and expel this with some blood through the vagina and out of the body. The **vagina** is that part of the female reproductive tract that opens to the outside of the body. It is the organ that receives the sperm on its journey to meet an ovum. The vagina is also a passageway for the birth of a baby. See Figure 29.

The **accessory glands** are the Bartholin glands located near the vaginal opening.

The **external genitals** consist of the many parts of the vulva and the entrance to the vagina.

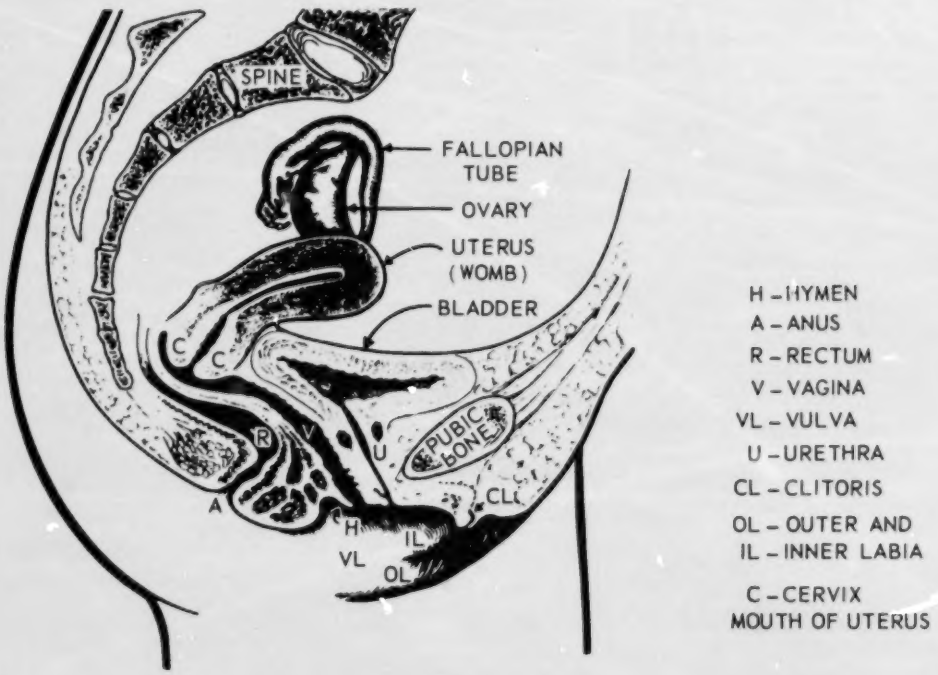


Figure 29. The female pelvis showing the organs of reproduction

THE ENDOCRINE SYSTEM

The endocrine system is composed of glands that produce one or more hormones that regulate and control certain functions of the body. It can be said that the endocrine system works similarly to the nervous system in its functions of communication and control. The nervous system sends nerve impulses by way of nerve fibers in order to regulate their activities. The endocrine system performs its job of regulation and control by sending hormones through the circulating blood. The organs of the endocrine system consist of the pituitary gland, the thyroid gland, the parathyroid gland, the adrenal glands, the Islets of Langerhans, the female sex glands, and the male sex glands. See Figure 30.

The **pituitary gland** is an organ no larger than a pea. It is attached to the central part of the floor of the brain and is protected by bony structure. Some of its main functions are the stimulation of growth, the stimulation of other glands such as the thyroid, adrenals, testicles, ovaries, and breasts. It also gives off a hormone that speeds up the kidney in the absorption of water. The pituitary holds a position of great importance. Its location at the floor of the brain certainly indicates this.

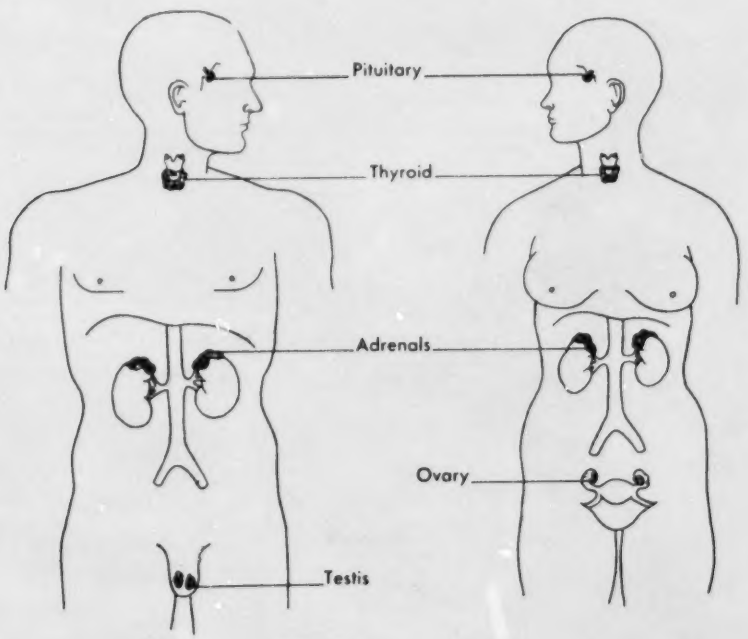


Figure 30. The endocrine glands - Not shown are the parathyroids which are on the back of the thyroid and the Islets of Langerhans that are minute cells located in the pancreas.

The **thyroid gland** is located in the neck just below the larynx. The hormone thyroxin is secreted by the thyroid and speeds up the release of energy from foods. If the thyroid secretes too much hormone, the release of food energy speeds up too much. This causes some individuals to appear nervous and overactive.

The **parathyroid glands** are very small and are located on the back of the thyroid. Their main function is to give off the hormone that controls the chemistry of the blood. They allow calcium to leave the bones and enter the blood thus increasing blood calcium. This is a very important function for brain cells. Heart cells cannot perform their task if the blood calcium is too low or too high. These glands must maintain a proper blood calcium balance at all times.

The **adrenal glands** are located on the top of each kidney. Each gland is composed of two parts. The adrenals give off hormones that assist in increasing glucose in the blood, to increase blood sodium and decrease blood potassium. From the inside of the adrenals, hormones are secreted that help prepare the body for emergencies of all kinds.

The **Islands of Langerhans** are minute clusters of cells that are located in the pancreas. These are the only glands in the body that cannot be seen with the naked eye. They are, as the name implies, little clumps of cells scattered throughout the pancreas like islands in the sea. The hormone that is secreted is insulin. Insulin's exact action is a mystery, but it has been established that it does permit blood sugar to be absorbed through the cell and to be used as energy by the body. A malfunction of this gland produces a condition called diabetes.

The **female sex glands,** the ovaries, secrete not only the ovum but hormones that control ovulation and menstruation.

The **male sex glands,** the testicles, produce the sperm plus hormones that develop the male sex organs and other male characteristics.

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